Moriond and the Top Quark Discovery

(or, “My Moriond Experience”)

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Fermilab

50th Moriond/QCD

Mar. 26, 2015

This Presentation

- What is not included in this talk:
  - Any scientific results: #'s, plots, comparisons (unless important to understand the atmosphere back then)
  - In particular, actual account of all the steps leading to the Top Quark Discovery at the Tevatron

This is not one of the conference's scientific contributions!

- What is this talk about?
  - Since this is the Moriond50 celebration, it is about Moriond
  - I'll give you my perspective as I started my active participation in the Moriond series of conferences (+ mention others)
  - Wherever possible I'll show photos (sorry if I appear in too many of them!)

This is a story that started 20 years ago…

From Archeology to History

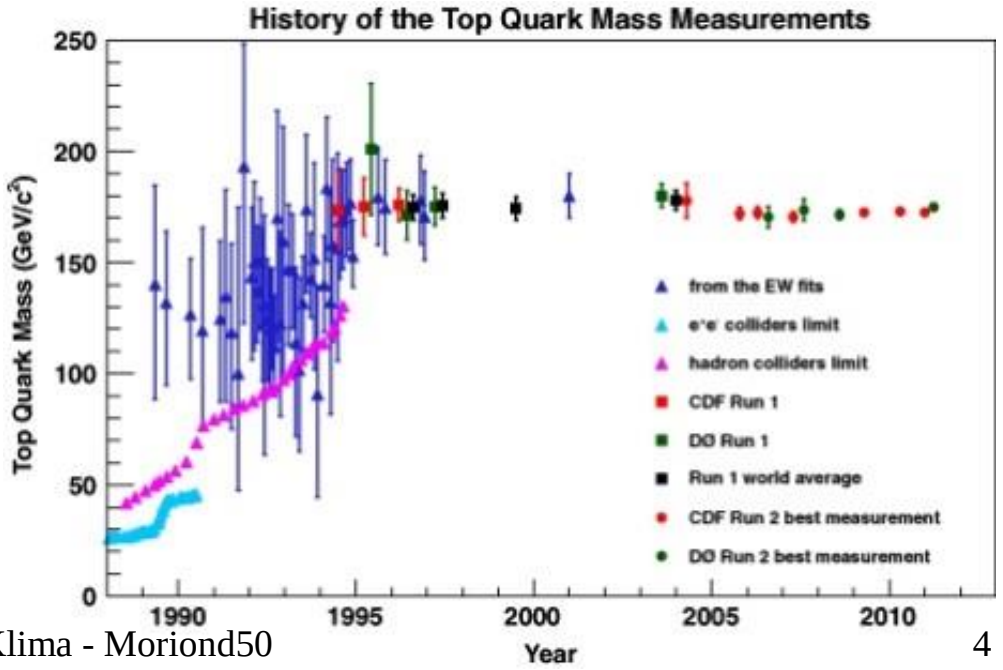
Fast Forward from Dino's Era to "only" 20 years ago…

Just to remind you, back then:

1. There were no laptops, no iPhones, no memory sticks,…
2. Presentations were made on real slides. Yes, plastic!
3. Everything done (meetings, decisions,…) was pretty localized/regional rather than global

We are in early 1994…

- The search for the Top quark in experiments worldwide has been going on for at least 17 years
- Top quark mass
  - Experiments have been producing limits, limits, and more limits
  - Theorists predictions and SM fits increasing steadily with new limits…
    - They started long before the 1990's…
    - 1970's – 13.5GeV
    - 1980's – 27GeV,…
  - Highest lower limit from the Tevatron is Dzero's at 131 GeV
  - Last SM fit reported at Moriond 1994 (by Bolek Pietrzyk) is ~177+/- GeV



Summer 1994

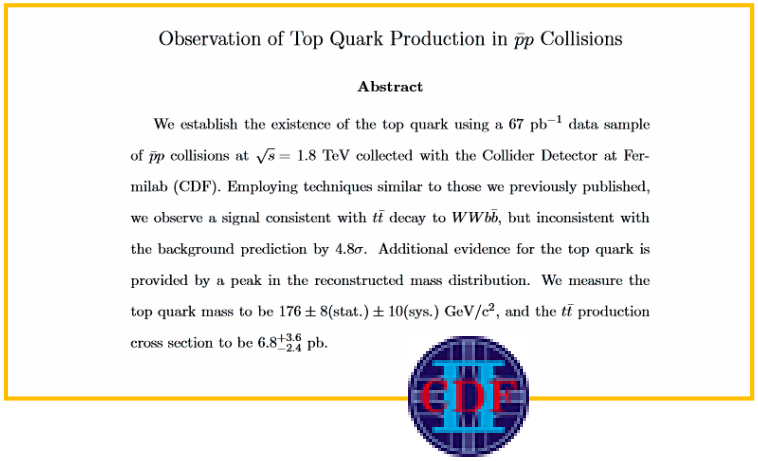
- At the Tevatron, the CDF and DZero collaborations finished analyzing their Run 1a data – both having similar ("expected") sensitivity to Top pair production
- CDF published a paper claiming evidence (2.8σ) for Top quark production with a cross section that is twice as large as predicted by SM
- Dzero's result (1.9σ) was consistent both with CDF's and with no signal – its "measured" $\sigma_{t\bar{t}}$ was consistent w/ SM
- Both experiments need more data - Run 1b is well underway
- Each collaboration decides (independently!) to double the data sample while analyzing the new data (Run 1b) exactly as before – sanity/consistency check

DZero and Conferences

- DZero has a Speakers Bureau (SB), headed by Sharon Hagopian (FSU), which assigns talks at conferences
- I am serving as convenor of the Top Physics analysis group at DZero, together with Nick Hadley (Maryland)
- We regularly recommend to the SB on candidates from the Top group for talks at conferences; obviously never ourselves
- In November ‘94 I received an unexpected invitation from Sharon (SB chair) to give a “Top Search” talk at Moriond
- I hesitated a bit since
  - There is nothing yet from Run 1b; just another “Search” talk
  - I don’t ski
  - Moriond is just another conference…
- I accepted since we had to send a name to the organizers

Top Quark Discovery – Early 1995

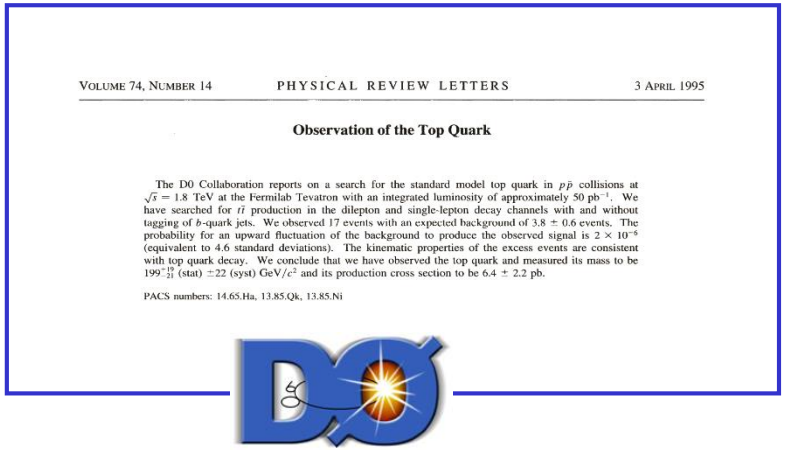
- Without going into too many details since they are not relevant here, early in 1995 the two collaborations found an overwhelmingly convincing signal for Top quark production
- Both submitted their discovery papers to PRL on Feb. 24, 1995 at 11am CST (not that anybody is counting…)



Observation of Top Quark Production in $\bar{p}p$ Collisions

Abstract

We establish the existence of the top quark using a 67 pb^{-1} data sample of $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV collected with the Collider Detector at Fermilab (CDF). Employing techniques similar to those we previously published, we observe a signal consistent with $t\bar{t}$ decay to $WWb\bar{b}$, but inconsistent with the background prediction by 4.8σ. Additional evidence for the top quark is provided by a peak in the reconstructed mass distribution. We measure the top quark mass to be $176 \pm 8(\text{stat.}) \pm 10(\text{sys.})$ GeV/c^2, and the $t\bar{t}$ production cross section to be $6.8^{+3.6}_{-2.4}$ pb.



VOLUME 74, NUMBER 14 PHYSICAL REVIEW LETTERS 3 APRIL 1995

Observation of the Top Quark

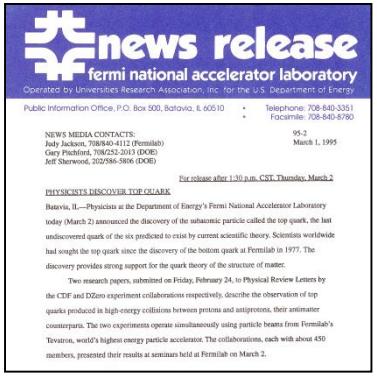
The D0 Collaboration reports on a search for the standard model top quark in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV at the Fermilab Tevatron with an integrated luminosity of approximately 50 pb^{-1}. We have searched for $t\bar{t}$ production in the dilepton and single-lepton decay channels with and without tagging of b-quark jets. We observed 17 events with an expected background of 3.8 ± 0.6 events. The probability for an upward fluctuation of the background to produce the observed signal is 2×10^{-6} (equivalent to 4.6 standard deviations). The kinematic properties of the excess events are consistent with top quark decay. We conclude that we have observed the top quark and measured its mass to be 199^{+19}_{-21} (stat) ± 22 (syst) GeV/c^2 and its production cross section to be 6.4 ± 2.2 pb.

PACS numbers: 14.65.Ha, 13.85.Qk, 13.85.Ni

- The world had to wait until…

Top Quark Discovery

- The official seminars from CDF and DZero were given on Mar. 2nd at Fermilab by the collaborations' spokespeople



news release
fermi national accelerator laboratory
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95-2
March 1, 1995

For release after 1:30 p.m. CST, Thursday, March 2

PHYSICISTS DISCOVER TOP QUARK

Batavia, IL—Physicists at the Department of Energy's Fermi National Accelerator Laboratory today (March 2) announced the discovery of the subatomic particle called the top quark, the last undiscovered quark of the six predicted to exist by current scientific theory. Scientists worldwide had sought the top quark since the discovery of the bottom quark at Fermilab in 1977. The discovery provides strong support for the quark theory of the structure of matter.

Two research papers, submitted on Friday, February 24, to Physical Review Letters by the CDF and DZero experiment collaborations respectively, describe the observation of top quarks produced in high-energy collisions between protons and antiprotons, their antimatter counterparts. The two experiments operate simultaneously using particle beams from Fermilab's Tevatron, world's highest energy particle accelerator. The collaborations, each with about 450 members, presented their results at seminars held at Fermilab on March 2.

THE NEW YORK TIMES **NATIONAL** FRIDAY, MARCH 3, 1995

Elusive Particle Found By Scientists in Illinois

Continued From Page A1

1977. Since the infancy of the universe shortly after the Big Bang estimated at 10 billion to 20 billion years ago — only the up and down quarks have survived in nature, the protons and neutrons that make up the nuclei of all atoms are built from combinations of these two quarks; the other quarks disappeared from the observed universe, but have been recreated by modern particle accelerators.

Dr. Leon M. Lederman, a winner of the Nobel Prize in Physics and a former director of Fermilab, said at today's meeting that he doubted there could be any more quark types but that "we know there's a lot of dark matter out in the universe that we can't identify."

"We're still in for a lot of surprises," he added.

But more important than merely completing the table of quarks predicted by theory, the top quark may now begin to shed light on a deep philosophical question: everything in the universe, from the most distant galaxy to a rose petal, is made of quarks. Were the masses and other properties of these particles determined by random chance, or by some fundamental unifying plan? If so, what is that plan, and how might gravity, the least understood of the four forces of nature, be related to it?

"This monster, compared with all the other quarks, is like a big cow-

bird's egg in a nest of little sparrow eggs," said Dr. Paul D. Grannis, a leader of the D0 group. "It's so peculiar it must hold clues to some important new physics."

"The top quark has turned out to be so heavy," added Dr. John Peo-

are one or more

beams.

"We're so elated by the discovery of the top quark that we haven't yet begun to sift all the data," said Dr. Boaz Klima of Fermilab, one of the leaders of the successful search. "But this particle is so astonishingly heavy that its decay may give us hints of a lot of other things, perhaps even of supersymmetric particles."

The quest for supersymmetric particles by the world's most powerful accelerators during the last decade has failed to turn up any evidence that they exist, but accelerators, they might be too heavy for even the biggest of present-day accelerators. If supersymmetric particles could be shown to exist, they might offer scientists a tool for learning how gravity is related to the other forces of nature: the electromagnetic force and the strong and weak nuclear forces.

Even when trillions of protons and antiprotons are made to collide in Fermilab's huge accelerator at combined energies of two trillion electron-volts, the creation of top quarks by the miniature fireballs remains a rare event.

Dr. Grannis of the D0 collaboration said today that his group, which has been running its detector on and off since 1992, has found 17 collisions resulting in evidence of the creation of a top quark. The team was able to calculate the mass of the particle as 199 billion electron-volts, give or take about 30 billion electron-volts. (Particle physicists measure mass in terms of its energy equivalent, because the units are more practical. Einstein's famous equation $E=mc^2$ defines the equivalency of mass and energy.)

For their part, according to Dr. William Carithers Jr., a leader of the rival CDF Collaboration, two separate counting techniques using the CDF detector have turned up a total of about 31 top quark events. The group calculates the mass of the top quark as about 176 billion electron-volts, give or take about 13 billion.

These results, the competing teams say, are in reasonably close agreement. At any rate, they agree that they have found the quark, and that there is only one chance in about one million that the results could have been caused by anything be-

The Top Quark: What Is It?

FILLING IN THE LAST BLANK The top quark is the last of the six types of quarks predicted to exist by the Standard Model, the physics theory describing the particles that make up all matter. Along with leptons (like electrons) and force-carrying particles called bosons, quarks are the building blocks of the universe.

THE STUFF OF ATOMS The nuclei of ordinary matter, like a hydrogen atom below, contain protons and neutrons made up of two kinds of quarks, up and down.

THE BIG BANG The other five quarks, which existed after the Big Bang, first appeared billion years ago and can now be produced only with particle accelerators. The top quark, the most massive quark by far, was also the most elusive. Two teams now say they have found it; they give overlapping estimates of its mass.

Hydrogen Atom

The 6 Quarks
Mass in millions of electron-volts

UP	CHARM	TOP
MASS: 5	MASS: 1,500	MASS: 176,000 to 199,000
DOWN	STRANGE	BOTTOM
MASS: 10	MASS: 180	MASS: 4,850

Found in ordinary matter

Forging a link between the physical and the metaphysical.

that the machine has at least 15 more years of useful life.

The stakes for the high-energy physics community are enormous, in terms of job security, the risks of failure and the promise of great prestige for leaders of successful experiments. Competition between physicists is often intense and sometimes bitter.

The CDF and D0 detector collaborations have gone to great lengths to avoid even looking at each others' experiments — a policy that persisted even today minutes before their joint seminar began.

"We know that some of the younger physicists on both sides have been exchanging pirated copies of our reports, but we've tried to suppress such exchanges," one physicist said. "Of course there is friction, but

New York Times
Mar. 3, 1995

"We're so elated by the discovery of the top quark that we haven't yet begun to sift all the data," said Dr. Boaz Klima of Fermilab, one of the leaders of the successful search. "But this particle is so astonishingly heavy that its decay may give us hints of a lot of other things, perhaps even of supersymmetric particles."

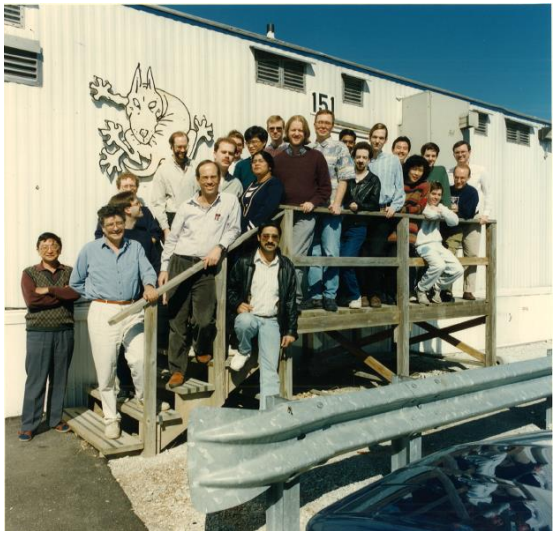
Beware! You are not in control of your message in the media!!

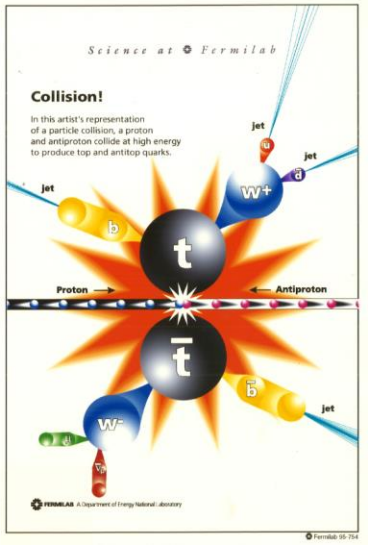
Top Discovery in the World News

- …and the word went out quickly…

March 1995

- A few more pics for the memories…





- …and I'm packing and heading to the airport – on my way to Moriond (if I'm not mistaken, that was Moriond30!)
- My talk is scheduled to be the very first of the conference…

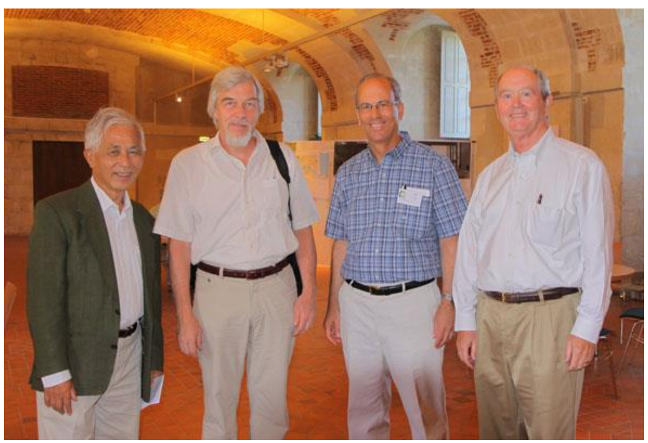
Perfect Timing !!!

Moriond 1995

Moriond 1995

Joining Moriond Organization

- After the conference Van invited me to join the program committee – I happily agreed
- Little did I knew back then that it's a life-long commitment…
- Moreover, "the brand" as some call it, consists of other conferences, e.g. Blois, Vietnam as well as many voluntary activities



Blois 2010

SAVOIE

VENDREDI 28 MARS 1997

dL PAGE FIL 3-73AB

Des veaux clonés à l'univers qui bouillonne

LES ARCS. Les rencontres scientifiques de Moriond se terminent. Passeport pour voyager au pays des clones, des quarks, et de la matière à 1 000 milliards de degrés.

Un éventail de recherches avec MM. Heyman, Klima et Blaizot

Très haute énergie et chaleur d'enfer pour mieux connaître la matière

MODE ACTU

Les grands défilés du pri

PRICEMAN - ALBERTVILLE

L'élégance au masculin

ALEXANDER CHAUSSURES

Elégance, choix et qualité

MEETING WITH THE PRESIDENT OF VIET NAM
TRUONG TAN SANG - HA NOI 24/8/2013

Moriond 1995 - 2015

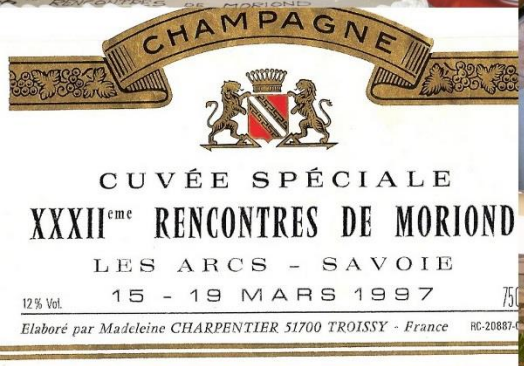
- Over the last 20 years my family and I had unforgettable experiences in Moriond at Les Arcs and La Thuile
- Much like all of you here, I enjoyed a lot the scientific (top notch!), the environmental (beautiful), and the organizational (superb!) aspects of Moriond
- It is impossible to sum it all up in a few minutes, even not by using photos taken over the years
- Nevertheless, the next 3 pages will attempt to do exactly that
- It is not doing justice to the conference, its organizers, our friends and colleagues
- However, it's a (first?) attempt

Enjoy!!

Moriond in Pics - Family

Moriond in Pics - Friends

Moriond in Pics - Celebrations



My Personal Perspective

- I enjoyed serving on the Moriond program committee for the last 20 years, working closely with amazing people
- I attended (yes, in person) all 20 Moriond s since 1995, watching closely how the conference evolved together with HEP while maintaining its unique spirit and atmosphere
- Moriond remains the best place to show new results and the most sought after conference in HEP
- Nowadays it appears regularly on the national media in many countries
- It has long moved from just-another-conference to becoming an Institution in HEP, maybe in all of science

Thanks

Many thanks to all those who helped creating and then organizing this wonderful series of meetings:
Van, Kim, Etienne, Jacques, Bolek, and many, many others